OD34A-2486: A review of sensors, samplers and methods for marine biological observations

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Abstract: Physical scientists now have Argo floats, gliders and AUVs to supplement satellites to provide a 3-D view of the time-varying global ocean temperature and salinity structure. Biogeochemists are catching up with evolving sensors for nitrate, optical properties, oxygen and pH that can now be added to these autonomous systems. Biologists are still lagging, although some promising sensor systems based on but not limited to acoustic, chemical, genomic or imaging techniques, that can sense from microbes to whales, are on the horizon. These techniques can not only be applied in situ but also on samples returned to the laboratory using the autonomous systems. The number of samples is limiting, requiring adaptive and smart systems. Given the importance of biology to ocean health and the future earth, and the present reliance on humans and ships for observing species and abundance it is paramount that new biological sensor systems be developed. This abstract will review recent efforts to identify core biological variables for the US Integrated Ocean Observing System and address new sensors and innovations for observing these variables, particularly focused on availability and maturity of sensors.

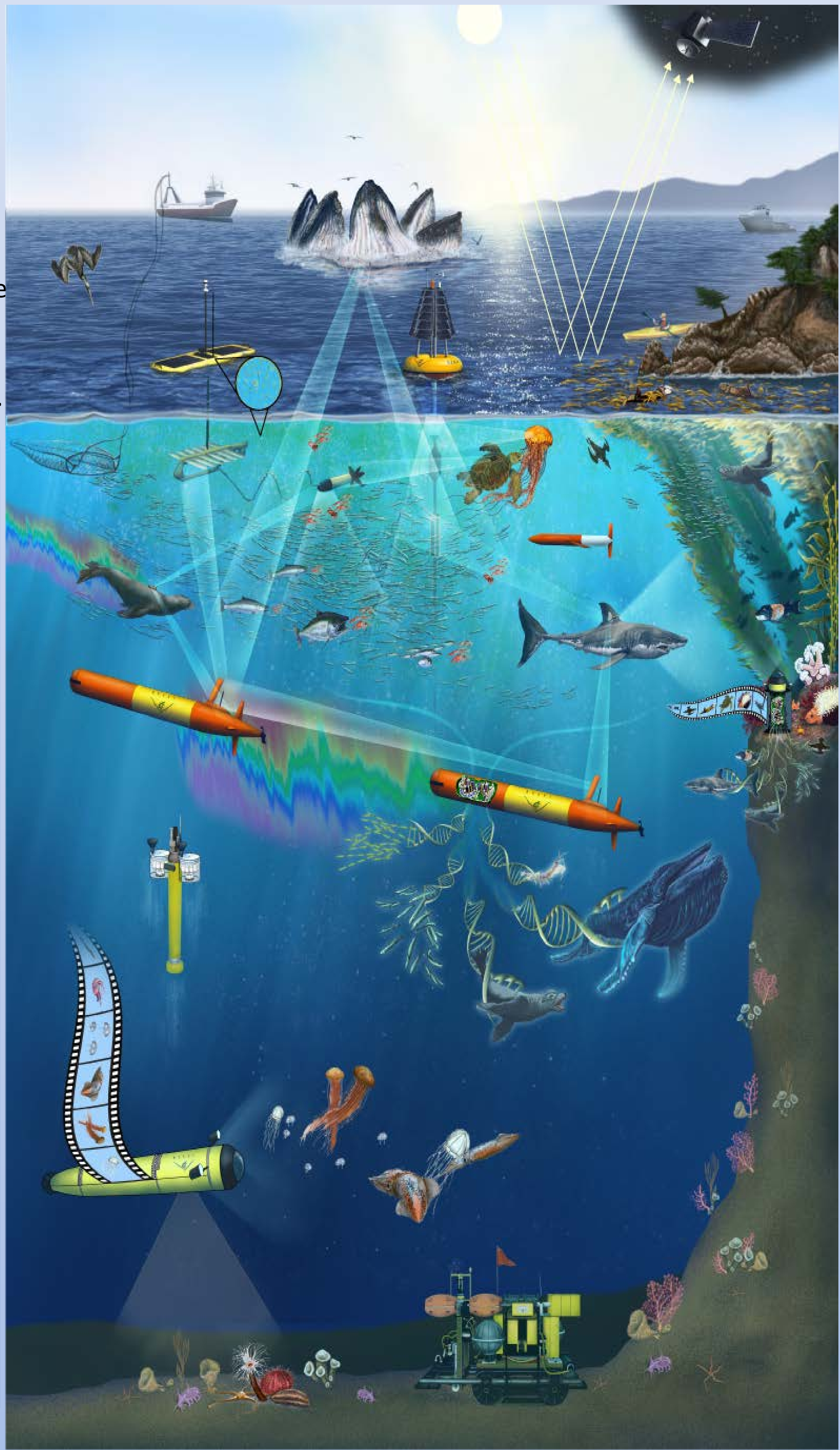
The context

National and international programs are embracing the need to observe life in the sea on a routine and sustainable basis. These observations are required to better understand and manage the impacts of climate variability and human pressures on ocean ecosystems and their health. It is abundantly clear that traditional means of identifying and quantifying the milieu of ocean species over the required time and space scales are not sustainable. Here we review the sensors, samplers and methods that could be used for the set of proposed **IOOS core biological variables** listed below.

Variable	Methods
Microbial[2] species and abundance and activity[3]	Microscopy, Sequencing, Flow Cytometry, Molecular techniques, FISH
Phytoplankton species and **abundance**[1]	Microscopy, Imaging, Pigments, Molecular techniques
Zooplankton species and abundance	Active acoustics, Nets, Microscopy, Profiling imaging instruments, Molecular techniques
Invertebrate species and abundance[4]	Active acoustics, Benthic grabs (infauna), Nets, Molecular techniques
Fish species and abundance	Active acoustics, Nets, Visual surveys (reefs), Photo/video surveys, Molecular techniques
Coral species and abundance	Visual surveys, Photo/video surveys, Hyperspectral imaging
Submerged vegetation species and abundance	Visual surveys, Photo/video surveys, Hyperspectral imaging, Airborne photography, Molecular techniques
Sea turtle species and abundance	Visual surveys, Mark-recapture, Tagging, Molecular techniques
Seabird species and abundance	Visual surveys, Mark-recapture, Tagging
Marine mammal species and abundance	Visual surveys, Mark-recapture, Tagging, Passive acoustics, Molecular techniques

[1] Phytoplankton species (but not abundance) is already an identified core variable.
[2] Here, "microbial" refers to heterotrophic bacteria and archaea. The distinction between microbes vs. phyto- and zooplankton was retained for simplicity and historical continuity.
[3] Microbial activity is included here rather than within biological vital rates, since it is more relevant for characterizing rates and quantities associated with the biogeochemical cycling of elements, which in turn influence primary and secondary production.
[4] Includes pelagic invertebrate nekton (as distinct from zooplankton) as well as benthic invertebrates.

New biological variables and recent advances are bolded



The cycle of life in the sea starts with primary producers converting inorganic elements to organics ones, cascades through the food web to top predators, and ends with the return of the organic elements to inorganic ones by microbes. The targeted biological variables can be grouped into **four functional groups**: 1) **Microbes, phytoplankton and microzooplankton**;2) **Zooplankton and forage species**; 3) **Larger fish, marine mammals, turtles and seabirds;** 4) **Submerged aquatic vegetation and benthic animals.** Each functional group shares common sampling and observational techniques.

Observation techniques:

- Physical sample collection using humans, CTDs, nets and in the future autonomous vehicles
- Visual/optics including microscopy, flow cytometry, video and remote sensing
- Acoustics, both active and passive
- Molecular and genetic methods (eDNA)
- Animal tags and telemetry

Platforms and sensors:

The need is for fixed and mobile platforms and continuous monitoring. The maturing of both biosensors and platforms opens new opportunities. The biological observing system will ultimately be comprised of a suite of platforms and techniques.

Platform	Observation Environment	Challenges
Mooring	Fixed location, good time resolution	Biofouling, expense, spatial coverage
Ships	Regional coverage	High cost, poor time and space coverage
Cable arrays	High power and bandwidth, supports multiple sensors	High operations and maintenance, poor spatial coverage
AUVs and Gliders	Lower cost, ability to deploy as fleets, steerable, could be global	Gliders have limited payload, AUVs better but still limited
Floats	Global deployments (ARGO)	Sensor power, volume, not steerable
Animal Tagging	Low cost, flexible coverage, matched biological and environmental data	Biofouling, battery life, payload/sensor size

Challenges and opportunities

- Global coverage, space & time resolution
- Integration of multiple platforms and techniques
- Communication between technology systems and software applications (interoperability)
- Continued development with improvements in automation, sensor power and sensor volume
- Data management and product generation
- Integration with the climate, physical and chemical ocean observing system
- Continuity over long timescales, funding
- Political concerns in coastal environments

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